CVP Cost Allocation Study
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Description of Analytical Tools

Name
Least-Cost Planning SIMulation model (LCPSIM)

Author
California Department of Water Resources (Ray Hoagland, Division of Planning and Local Assistance)

Categories
Economic optimization, urban water system simulation

Main Features and Capabilities
- Spatial scale at hydrologic region/planning area.
- Simulation runs through a hydrologic sequence of supplies and rainfall-correlated demands at a specified level of future demand (e.g., 2020) on a *yearly* time step.
- *Reliability enhancement options* are adopted based cost minimization ($ per thousand acre-feet) and include long-run demand reduction and supply augmentation measures, such as toilet retrofit and wastewater recycling, to reduce frequency, magnitude, and duration of shortage events.
- Cost of *reliability enhancement* (thousands of $) expressed as a function of the level of adoption of *reliability enhancement options* (thousands of acre-feet).
- S*hortage contingency measures* such as water transfers (based on minimizing cost among transfer options) and shortage allocation by *water use category* in the region/planning area (residential, commercial, industrial, and large landscaping); are used for shortage management.
- *Expected economic losses* (thousands of $) are produced by an *economic loss function* which uses the percentage size of shortage (foregone use) events generated by the simulation as well as the percentage size of each *water use category*.
- *Demand hardening* is computed as a function of the level of use of demand reduction measures and used to adjust *expected economic losses*.
- Cost of *unreliability* (thousands of $) is expressed as a function of the level of adoption of *reliability enhancement options* (thousands of acre-feet) and includes *expected economic losses* as well as the expected costs of *shortage contingency measures*.

- *Reliability management cost* (thousands of $) includes the cost of *reliability enhancement*, the cost of *unreliability*, and the cost of carryover storage operations, conveyance, treatment, and distribution.
- The *least-cost reliability management plan* is identified by minimizing *reliability management cost* expressed as a function of *reliability enhancement*.
- Operations of *carryover storage facilities* available to the region/planning area (including ground water banking) are used for reliability management in LCPSIM.
- Priority-based objective, mass balance-constrained linear programming is used to operate *carryover storage facilities* and balance (to the extent possible) available supplies with demands on a yearly basis.
- The State Water Project is treated as the residual source of supply: SWP supply quantities available for delivery to the region/planning area which are unusable and unstorable in any year of the simulation are identified.

Applications

The model has been applied to the San Francisco Bay and South Coast hydrologic regions at the 2020 level of demand to determine the regional economic benefit value of additional State Water Project deliveries.

Calibration/Validation/Sensitivity Analysis

Validation of LCPSIM has not been performed due to lack of comparable historical data available for a region to check against model results and the fact that LCPSIM was designed as a normative rather that a positive (predictive) model. Verification is being performed in a peer review process (see below). Sensitivity analysis, which does not require actual historical data, can be performed independently of calibration/validation to test the sensitivity of model results against key input parameters. Limited sensitivity analyses have been part of the peer review process.

Peer Review

Members of the Bay-Delta Authority Common Assumptions Economics Workgroup has been involved in reviewing and suggesting modifications to LCPSIM since mid-July of 2004. This work was completed in 2005.

Anatomy of LCPSIM

Conceptual Basis

Conceptually, the primary objective of LCPSIM is to develop an economically efficient regional water management plan based on the principle of least-cost planning. At the least complex level, LCPSIM evaluates the effect of the availability of additional imported water supplies on the net value of adopting regional long-run water management options such as recycling or toilet retrofit programs and on costs and losses associated with shortage events. At a more complex level, LCPSIM evaluates the availability and use of contingency strategies to mitigate the economic impacts of shortage events, such as short-term water market transfers, use of supplies from carryover storage (conjunctive use), and water allocation programs. These strategies can affect the economically efficient level of adoption of the long-term water management measures. Conversely, the level of adoption of long-term measures can influence the effectiveness of the contingency management strategies and, therefore, their use.

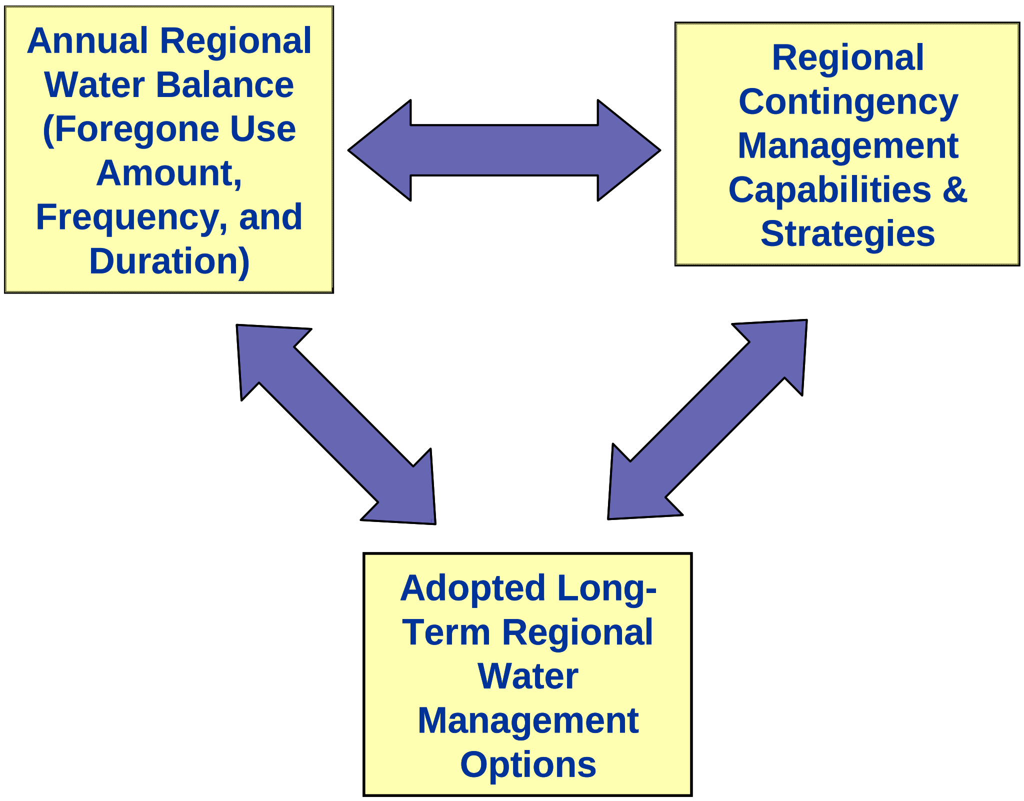


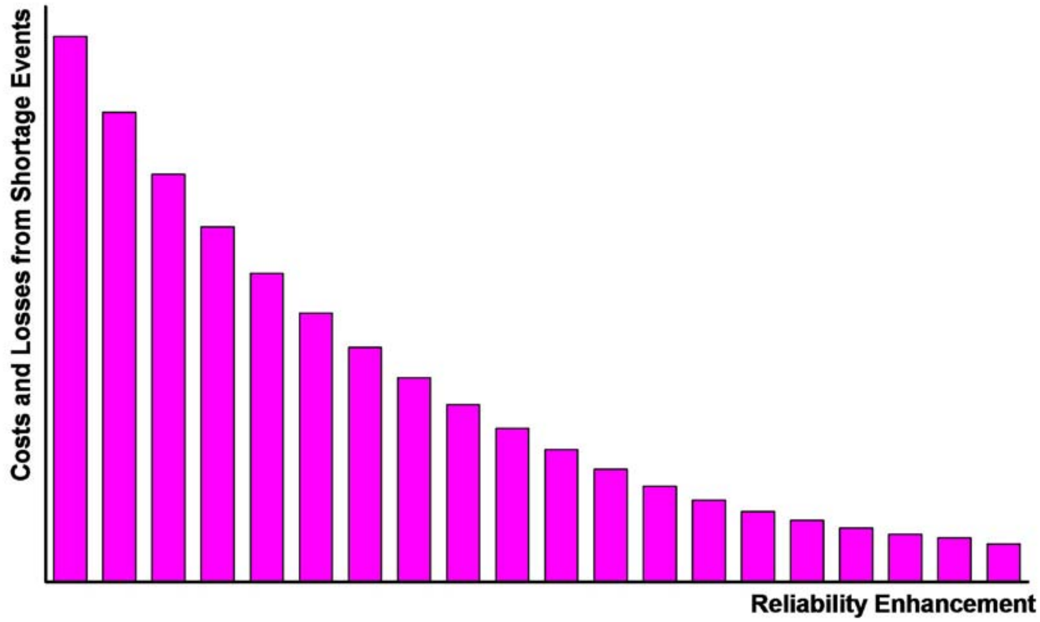
Figure above depicts the primary planning interrelationships important for evaluating, from a least-cost perspective, the cost of alternative plans to increase the reliability of a hypothetical water service system. The link between the investment in long-term water management options and the size and frequency of shortages is shown, as is the link between shortage contingency management strategies and the costs and losses associated with foregone use: a greater investment in the ability to manage shortages will lessen the economic costs and losses due to foregone use when they occur.

Theoretical Basis

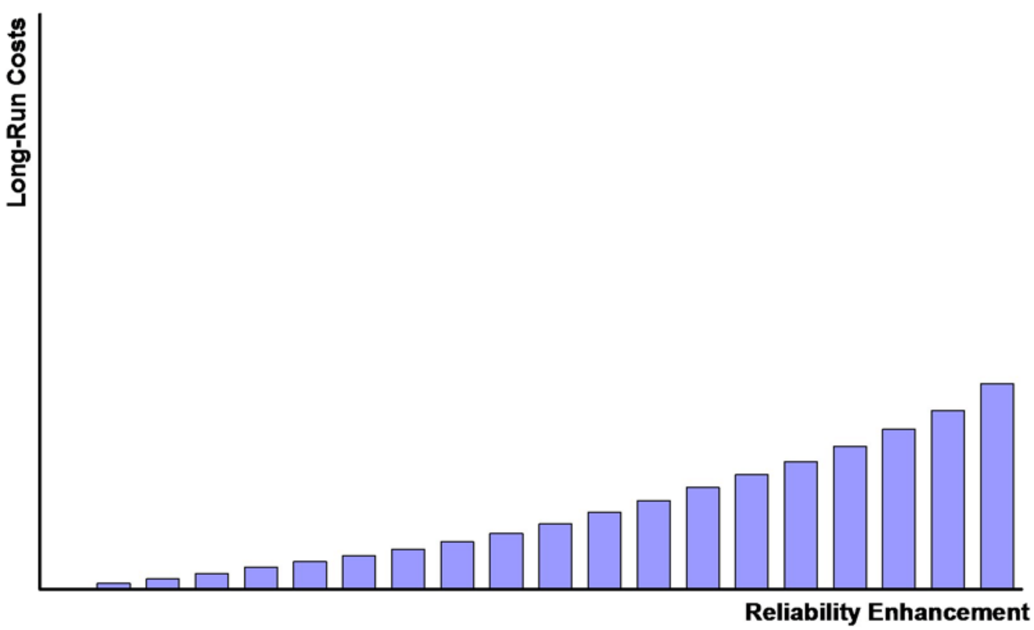
The theoretical basis of LSPSIM is to minimize the total cost of *reliability management*, the sum of two costs: *cost of unreliability* and the *cost of reliability enhancement*, recognizing that the former is inversely related to the latter.

The *cost of unreliability* is most directly measured by forgone use. Foregone use occurs when residential users or businesses, for example, have established a lifestyle or a level of economic production based on an expected level of water supply available for use and that expectation is not realized (i.e., a "shortage event") in a particular year or sequence of years.

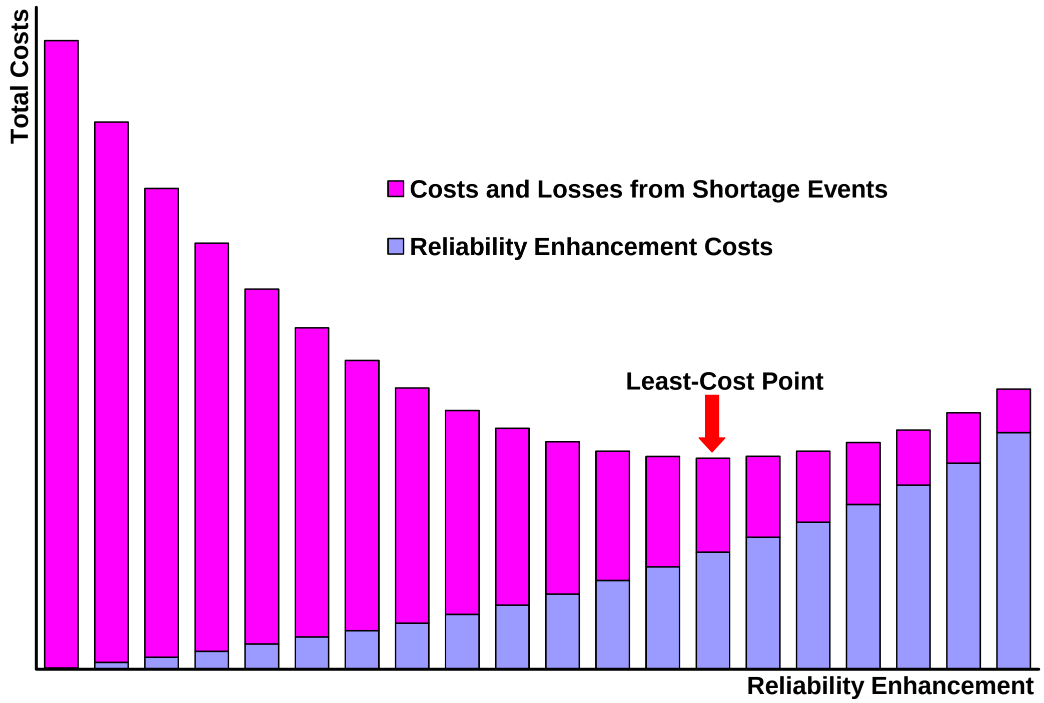
Figure below illustrates the expected decrease in the costs and losses associated with foregone use as water management options are adopted to enhance reliability. This enhancement may be obtained from either supply augmentation or demand reduction options.



The next figure shows incremental effect of enhancing reliability on long-run water management costs. The assumption is made that options will be adopted in an order inversely related to their unit cost, including any associated treatment and distribution costs: the least expensive options are expected to be adopted first.



When the information from the two Figures above is combined, it results in a total cost tied to the level of reliability enhancement as shown in the following figure:



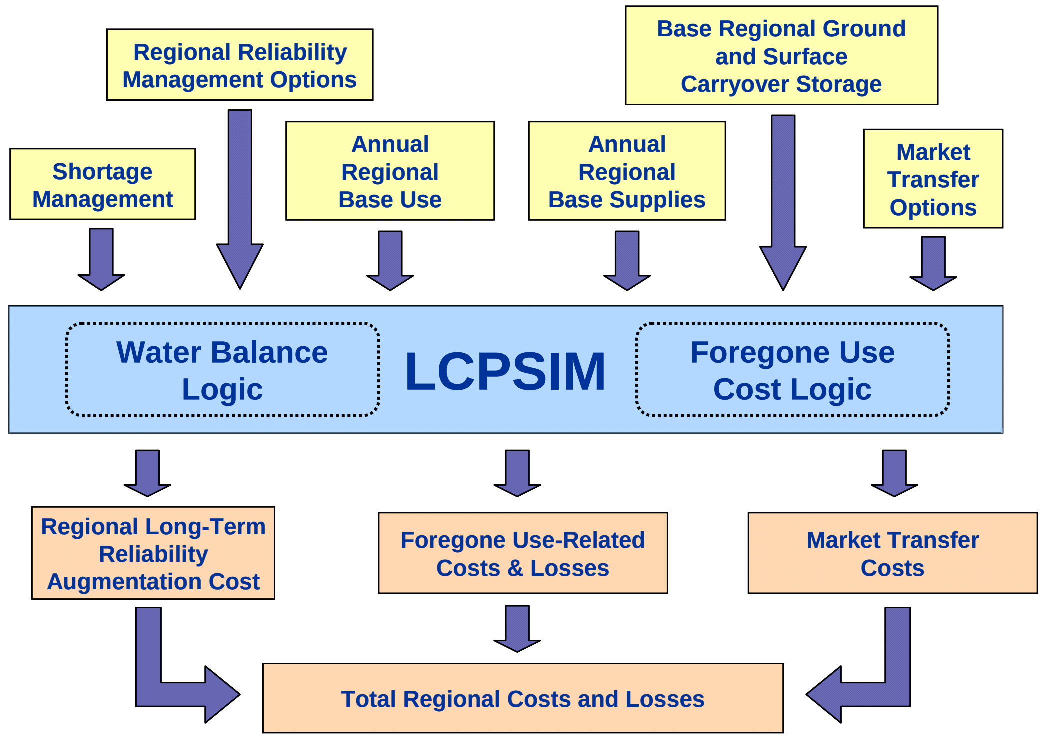
The least-cost point represents the economically efficient plan, that is, it is the level of reliability enhancement beyond which it is economically less costly, compared to the cost of additional reliability enhancement, to accept the expected costs and losses from foregone use. Conversely, at any level of enhancement less than this, compared to the expected costs and losses from foregone use, it is less costly to enhance reliability. This solution is the least-cost reliability management plan.

Numerical Basis

In LCPSIM, a priority-based objective, mass balance-constrained linear programming solution is used to simulate regional water management operations on a yearly time-step, including the operation of surface and groundwater carryover storage capacity assumed to be available to the region/planning area. The system operations context allows the evaluation of the reliability contribution of additional regional long-term reliability enhancement options, including increased carryover storage capacity, to account for any synergistic interactions between options. The cost of adding those measures is determined using a quadratic-programming algorithm which minimizes the cost of each incremental addition. The sum of the cost of unreliability (which decreases) and the cost of the adoption of the reliability enhancement options (which increases) is mapped against the increasing level of use of those reliability enhancement options and a polynomial smoothing function is fitted. The polynomial function is then solved for the least-cost reliability management plan.

Input and Output

Figure below shows the general types of both the *Input* data required by LCPSIM and the resulting *Output* information generated by the model.



Data Management

LCPSIM was developed to use CALSIM II output as its primary data source. Excel© VBA macros are used to extract time series delivery data from CALSIM II DSS files and store them as the ASCII files used by LCPSIM. Data on other regional deliveries available as time-series data are also stored as ASCII files. All system operations and regional options parameters used by the model are stored as ASCII files. Results from the model are exported in Excel® file format. Excel® VBA macros are available for interfacing LCPSIM results with CALAG shadow values to calculate the net value of "excess" urban supplies made available for agricultural use in wet and above normal years and transfers from agricultural use to urban use in dry and critical years. All input and output data are stored locally.

Software

LCPSIM software runs on Windows 95® and above and is designed to be data-driven in order to represent different water service systems without changing the model code. The semi-self-documenting source code is written in the Delphi® language (formerly, Borland Object Pascal) with an emphasis on modularity to facilitate extending the model, if needed. Compiling the source code requires Version 6 (or greater) of the Borland Delphi® Integrated Development Environment. A Windows® help file is callable from the program (a users' manual is not yet available). To run, LCPSIM requires either a proprietary quadratic programming solver DLL from Frontier Systems (very fast) or a free quadratic programming solver DLL developed by Csaba Mészáros at the MTA SZTAKI, Computer and Automation Research Institute, Hungarian Academy of Sciences, Budapest, Hungary (much slower). Licensed Delphi® IDE users can also freely distribute the Visual Components Formula One® ActiveX component required by LCPSIM.